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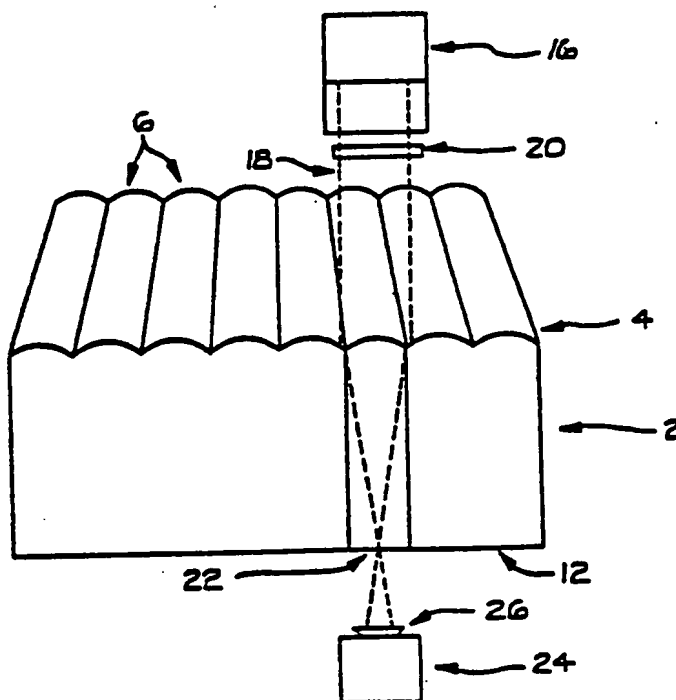
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(54) Title: OPTICAL DATA STORAGE AND READOUT APPARATUS

(57) Abstract

An optical apparatus for high density storage and readout of binary data (14), which is insensitive to wobbling or eccentric motion of the recording disk (8). Parallel light (18) from a laser (16) is focused onto one of numerous data lines (14) on a photosensitive surface (12) by an array (4) of cylindrical lenses; a cylindrical lens (20) at right angles to the cylindrical array (4) focuses the beam (18) in the direction of the data line (14), producing a point image (22). The lens array (4) and photosensitive surface (12) are on opposite sides of a transparent recording disk (8), so that there is no relative motion of each data line (14) and its corresponding lens, essentially eliminating the effects of eccentric or wobbling motion of the recording disk (8). A shuttered (26) photosensor (24) on the side of the recording disk opposite the laser (16) intercepts all of the light diverging from the point image (22) on the recording disk (8). Binary data is recorded on each data line (14) by pulsing the laser (16) for each 1 bit as the recording disk (8) is rotated, with the photosensor (24) shutter (26) closed. For readout the laser (16) is operated continuously at low power, the shutter (26) is opened, and the photosensor (24) output is monitored as the recording disk (8) is rotated.

Variations in the photosensor (24) output correspond to the data previously recorded. By means of slightly rotating the entire optical system about an axis parallel to the cylindrical lens array (4), numerous data lines (14) may be selected for recording or readout, for each lens of the cylindrical lens array (4).



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OPTICAL DATA STORAGE AND READOUT APPARATUS

TECHNICAL FIELD

5 The invention pertains to optical systems
which allow high density recording of data on a data
surface. Such systems have particular application in
10 the recording of binary data constituting the input or
output for computer systems, though the present
invention is not so limited in its application.

BACKGROUND ART

15 In some computer operations, very large
quantities of data must be very rapidly made available
as input for the computer. Similarly, very large
quantities of computational results may be rapidly
generated as the output of the computer operations.

20 Depending upon the size of the computer
memory and the nature of the computer operations,
there may be a need to temporarily transfer the
results of intermediate computer calculations to a
temporary external data storage apparatus, and to
subsequently transfer such results back into the
25 computer as input data for subsequent calculations.

30 Such a data storage apparatus should be
capable of achieving a high density of data storage,
should allow rapid writing and readout of stored data,
and must provide completely reliable data tracking -
i.e., means for ensuring that particular items of
stored data may be reliably located and read out as
desired.

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1 In the case of such apparatus which involves
a moving data recording surface, the need for high
density of data storage commonly gives rise to a
serious data tracking problem associated with
5 eccentric or wobbling motion of the surface, or
dimensional changes caused by temperature and humidity
effects, which can easily cause misrecording or
misreading of data. Also the maximum data rates for
writing and reading are limited by the capabilities of
10 the tracking and focusing mechanism to follow rapid
deflections of the data track.

Since computer data is generally first
recorded in binary form, such data may be recorded by
using an optical system to focus a beam of light to an
15 image on a photosensitive data surface, the two binary
states being represented by an image recorded upon
said surface, and by the absence of such an image.

British Patent No. 1235192 to Johnson
et al. discloses a photographic apparatus for viewing
20 still or motion pictures, which can also be used as a
camera. A matrix of lenses is movable, together with
(in fixed relation) a film recording individual images
for each lens of the array, past an objective lens, so
that successive lenses of the lens array may be
25 brought into alignment with the optical axis of the
objective lens. Individual images may be successively
viewed or recorded, either by trans-illuminating a
film already having such images, or illuminating an
external object to be photographed. This photographic
30 apparatus is designed for processing an array of
ordinary photographic images, and is not suitable for
processing a high density array of binary data.

As described in detail below, applicant's
apparatus provides for much higher density binary data
35 storage through use of an array of cylindrical lenses,
and a crossed cylindrical lens, focusing parallel
light to point images falling on an array of data
lines formed by the cylindrical lens array. Through

1 use of a rotational optical data tracking system,
numerous data lines may be recorded and later read
under each lens of the cylindrical lens array.

United States Patent No. 3,427,942 to
5 Browning (hereinafter "Browning I") discloses a
photographic apparatus and special film strip,
exhibiting one useful property of the Johnson patent.
The film strip, which has a transparent film base, has
a series of fresnel lenses on half of the film
10 surface, and has a photographic emulsion on the other
half, on the reverse side of the film. Light from an
object to be photographed passes through the film base
and the fresnel lenses, is reflected by a prism, and
then focused upon the emulsion, by the fresnel lenses.
15 This apparatus, like that of the above-referenced
British patent, deals in part with the problem of
eccentric motion of the recording surface, in that
there is no translational relative motion between the
focusing lenses and the emulsion.

20 However, the apparatus of Browning I
exhibits several problems avoided by applicant's
apparatus. One is a defocusing effect associated with
any wobbling motion of the moving film in a direction
normal to the film surface. Such motion will change
25 the distance from the film strip to the prism, and
thus change the total optical path length from the
fresnel lens to the film emulsion, by twice the
amplitude of the wobble. Applicant's apparatus avoids
such an effect, in that applicant's cylindrical lens
30 array and photosensitive data surface are on opposite
sides of one transparent disk, in fixed relationship
to one another, so that there is no relative wobble
motion between them.

35 The Browning I film strip is divided into
one half bearing the strip of fresnel lenses, and the
other half containing the film emulsion. By contrast
applicant's geometry uses the entire disk area for the
lens array and data surface. Moreover, applicant's

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1 simpler geometry avoids the necessity of an optical component (the prism) in the optical path between the lens array and the data surface.

5 And applicant's geometry is better adapted to high density storage of binary data, through the use of cylindrical rather than spherical lenses.

United States Patent No. 3,818,148 to Dickopp discloses an optical system for reading information stored in undulations upon a surface, in which parallel light rays pass through a transparent recording element bearing the surface undulations containing the information. The surface undulations have a lens-like action, producing convergence or divergence of the light rays, which are measured by an optical system after passing through an aperture located in the region of the average "focal point" of the convex undulations. Variations of the optical system output as the aperture is moved horizontally correspond to to the pattern of the surface undulations. Such an apparatus would also exhibit a defocusing effect due to wobbling motion normal to the recording element, which motion changes the distance to the lens, thus affecting the optical system output. The patent points out that it is desirable to maintain a substantially constant distance between the recording element and the plane of maximum convergence of the light rays (col 2, line 59 - col 3, line 22), and acknowledges that performance of the system can be somewhat affected by wobble of the recording element, although claiming that wobble presents less of a problem than in prior art systems (col 7, lines 30-50; col 9, line 67 - col 10, line 13).

Applicant's apparatus avoids any such wobble effect, because the distance from the cylindrical lens array to the data surface is fixed, and because the output of the photodetector used by applicant is independent of the distance from the data surface to the photodetector, so long as one uses a photodetector

1 of sufficient width to intercept the entire beam
diverging from the data surface. Applicant's
apparatus, moreover, may be used both for recording
and readout of data, whereas that of Dickopp is usable
5 only for readout of data already stored in the surface
undulations.

United States Patent No. 3,999,008 to
Bouwhuis, et al. discloses an apparatus for reading
data stored in tracks on a surface, in which a read
10 beam is focused by an objective lens onto the data
tracks, and reflected radiation is focused upon a
radiation detector. The surface bearing the data
tracks has a structure containing periodic vertical
excursions which cause a calibrated wobble effect:
15 periodic focusing and defocusing of the read beam as
the data surface moves, corresponding to the known
vertical excursions. An oscillating signal caused by
these periodic vertical excursions allegedly may be
used to correct for defocusing of the read beam, for
20 example by moving the objective lens, which may be
mounted in a loudspeaker coil moved by such signal.
The approach of this patent is not to eliminate
wobble, but rather to provide a means of correcting
for it, by a calibrated built-in wobble. Applicant's
25 apparatus offers the advantage of simply eliminating
any wobble effect, making unnecessary the corrective
measures of Bouwhuis.

United States Patent No. 2,923,781 to
Gordon, et al. discloses an apparatus for motion
picture sound recording, in which sound-modulated
30 light is focused by an optical system involving two
cylindrical lenses, onto a slit aperture inclined at
an angle to a film grating. In one embodiment the
film grating comprises parallel cylindrical lenticules
above the light sensitive surface. However, in the
35 geometry of this apparatus the light rays are not
parallel but are converging when they reach the
aperture and the lenticules. The performance of the

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1 system could thus be affected by any wobble of the
film in the direction normal to the film. In
applicant's apparatus, the light rays are parallel
when they reach the cylindrical lens array, so that
5 the performance of the system is not affected by such
wobbling motion.

United States Patent No. 4,020,278 to Carra,
et al. discloses a data carrier apparatus in which the
data is stored in the form of small depressions on a
10 surface. Parallel light is focused upon the data
carrying surface by an objective lens. Photodetectors
on the opposite side of the data surface sense changes
in light paths corresponding to the presence of the
depressions representing the data. The apparatus is
15 usable only for reading data already recorded in an
embossed pattern of depressions, whereas applicant's
apparatus may be used for recording data as well as
for readout.

United States Patent No. 3,980,818 to
20 Browning (hereinafter "Browning II") discloses a
recorder and reproducer apparatus having one
embodiment in which a laser beam passes through an
array of tiny lenses before being focused by a
microscope objective lens onto a record disk. But in
25 this apparatus, the lens array is entirely separate
from the record disk. The Browning II apparatus would
thus be subject to the wobble effect discussed above,
due to relative motion between the record disk and the
lens array. As already noted, applicant's structure
30 avoids any such effect, in that the applicant's lens
array and data surface are on opposite sides of a
single disk.

DISCLOSURE OF INVENTION

The invention is an optical apparatus for
35 high density and high rate storage and readout of
binary data, which is insensitive to eccentric or
wobbling motion of the recording element. The
invention comprises, in geometrical linear sequence: a

1 laser which produces a parallel beam of light of the
correct diameter; a convex cylindrical lens; a
transparent recording plate, having an array of
parallel identical short focal length convex
5 cylindrical lens surfaces (hereinafter sometimes
termed "cylindrical lens array") on the first side
thereof, and a data surface on the second side
thereof; and a photosensor having a shutter, on the
side of the recording plate opposite the laser. The
10 data surface is a coating of a material which will
change light transmitting characteristics upon
exposure to focused laser light.

The thickness of the recording plate is
equal to the focal length of the convex cylindrical
15 lens surfaces, so that parallel light incident upon
one of the cylindrical lens surfaces is focused to a
line upon the data surface.

Since the cylindrical lens array cannot
focus light in the direction of the axes of the
20 cylindrical lens surfaces, the convex cylindrical lens
is aligned with its axis perpendicular to the axes of
the cylindrical lens surfaces, and is positioned at a
distance from the data surface of the recording plate,
such that its focal point lies on the data surface.

25 The beam width of the laser beam is slightly
greater than the width of each of the converging lens
surfaces.

The above-described lens geometry causes the
laser beam to be focused to an approximately point
30 image upon the data surface.

To record binary data the recording plate is
moved longitudinally, in the axial direction of the
cylindrical lens array, the laser is pulsed at high
power for each 1 bit, with the photosensor shielded by
35 the shutter, and the binary data is thus recorded as a
series of point images lying upon a data line on the
data surface, each such image being a point at which
the light transmitting characteristics of the data

1 surface has been changed, and each data line being
parallel to the axis of the cylindrical lens array.

5 In order to read out the binary data, the
laser is switched to low power continuous operation,
the shutter is opened, and the recording plate is
again moved axially. The laser beam and photosensor
in this mode read the data previously recorded upon a
data line, which is reflected in time variations of
the photosensor output.

10 The apparatus includes a means for rotating
the optical system about the axis of a given lens of
the cylindrical lens array. When the optical system
is rotated slightly about such axis, the position of
the data line will be shifted slightly upon the data
15 surface. In this manner a set of numerous data lines
(of the order of 200) may be written beneath each lens
of the cylindrical lens array. The apparatus may be
moved from one set of data lines to another by mere
translational motion of the optical system or the
20 recording plate.

Because the light rays reaching the
cylindrical lens array in each cross sectional plane
of the lens array are parallel, the output of the
apparatus is relatively insensitive to wobbling motion
25 of the recording plate, in a direction perpendicular
to the plate, because such motion has only a slight
defocusing effect (by changing the distance to the
first cylindrical lens).

The tracking performance is also insensitive
30 to eccentric motion of the recording plate, in the
direction along the plate surface and perpendicular to
the axis of the cylindrical lens array, since in such
motion each data line being recorded or read moves
together with the particular converging lens surface
35 of the cylindrical lens array which focuses the laser
beam upon that data line.

The tracking performance is also insensitive
to the speed of the recording plate because tracking

1 is inherent in the optical design and occurs at the
speed of light. Therefore, much greater data rates
can be achieved than in previous systems which use
5 electro-mechanical tracking mechanisms of limited
following capability.

The invention is most conveniently used in
an embodiment using a circular recording disk in lieu
of a linear recording plate, since the recording disk
10 is usable with a turntable drive mechanism. In this
embodiment, the cylindrical lens array is formed of
circular rings on one surface of the recording disk,
the principles of the invention being generally the
same as described above.

15 It is an object of the present invention to
provide an optical apparatus of comparatively simple
design suitable for high density storage of binary
data.

20 It is another object of the invention to
provide such an apparatus which also allows readout of
the stored data.

25 It is another object of the invention to
provide such an apparatus which is not sensitive to
eccentric or wobbling motion of the recording element,
so as to eliminate any need for precise mechanical
drives or tracking equipment.

It is another object of the invention to
provide an apparatus which can operate at higher write
and read data rates than previously possible.

BRIEF DESCRIPTION OF THE DRAWINGS

30 Figure 1 is a perspective view of one
embodiment of the invention.

35 Figure 2 is a cross-sectional view of a
portion of the invention, illustrating the effect of
eccentric (horizontal) motion of the recording plate.

Figure 3 is a cross-sectional view
illustrating the selection of different data lines by
relative rotation of the recording plate and the

1 optical system.

Figure 4 is a perspective view of the embodiment employing a recording disk, illustrating a means for rotating the optical housing with respect to the recording disk.

BEST MODE OF CARRYING OUT THE
INVENTION AND INDUSTRIAL APPLICABILITY

Referring now to the drawings, wherein like reference numbers denote like or corresponding parts, the apparatus employs a recording plate 2, which is a flat transparent plate having on its upper surface a cylindrical lens array 4 of convex cylindrical lens surfaces 6, with parallel axes, each having a focal length f_1 equal to the thickness of the recording plate 2. In one convenient embodiment, the recording plate 2 is in the form of a circular recording disk 8, which can be rotated about the disk axis by a turntable-type drive motor 10, as illustrated in Fig. 4. In this embodiment each of the cylindrical lens surfaces 6 lies on a circle concentric with recording disk 8. The lower surface of recording plate 2 is covered with a data surface 12, which is a coating of a material which will change its light transmitting characteristics upon exposure to focused laser light. Such a surface may be formed, for example, of a 5-micron-thick coating of tellurium, which will be ablated by the focused laser light; or of photosensitive material, which can form a photographic image; or of a ferromagnetic material such as iron oxide which will cause rotation of the direction of polarization of the laser light.

Parallel light incident upon the upper surface of recording plate 2 will be brought to focus by cylindrical lens array 4 in one or more parallel data lines 14, which are parallel to the axes of cylindrical lens surfaces 6. The precise positions of data lines 14 will, of course, depend upon the angle of incidence of the parallel light rays, as further

1 discussed below.

Located above recording plate 2 is a laser 16, capable of either high power pulse modulated operation, or low power continuous operation, which is simply one convenient means for generating a beam of essentially parallel light rays, the laser 16 being oriented with its beam 18 directed onto the upper surface of recording plate 2, in a direction perpendicular to the axes of cylindrical lens surface 6. Laser 16 is so operated as to produce a beam having a width slightly greater than the width of the individual cylindrical lens surfaces 6 of cylindrical lens array 4.

Since each of the cylindrical lens surfaces 6 of cylindrical lens array 4 would by itself focus beam 18 to form a line rather than a point image, a convex cylindrical lens 20 is located between laser 16 and recording plate 2, so positioned as to intercept beam 18, and is aligned with its axis perpendicular both to beam 18 and to the orientation of the axis of the cylindrical lens surface 6 receiving beam 18. Cylindrical lens 20 is so positioned that its focal point lies on data surface 12. The focal length f_2 of cylindrical lens 20 is, of course, greater than the thickness f_1 of recording plate 2. Cylindrical lens 20 focuses the light of beam 18 in the direction of data line 14, which cylindrical lens surface 6 cannot. Thus the combined effect of cylindrical lens 20 and cylindrical lens surface 6 is to produce an approximately point image 22 upon data surface 12.

In the embodiment in which recording plate 2 is in the form of a recording disk 8, laser 16 is oriented such that beam 18 is always perpendicular to the axis of cylindrical lens surface 6 at the point of incidence of beam 18 onto recording disk 8. This is accomplished if laser 16 is so oriented that the direction of beam 18 lies entirely in the plane defined by the axis of recording disk 8 and the

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1 particular radius of recording disk 8 passing through
image 22. In this embodiment, cylindrical lens 20 is
oriented with its axis perpendicular to beam 18 and
lying in the same plane. Thus cylindrical lens 20 is
5 always perpendicular to the axis of cylindrical lens
surface 6 at the portion of cylindrical lens surface 6
struck by beam 18, so that an image 22 remains an
approximately point image as recording disk 8 is
rotated.

10 Located below recording plate 2 is a
photosensor 24, having an aperture slightly larger
than required to intercept all of the light of beam 18
diverging from image 22. It is readily seen that such
aperture must be greater than (DW/f_1) , where D is the
15 distance from data surface 12 to photosensor 24, W is
the maximum width of beam 18 at the point of incidence
of beam 18 with recording plate 2, and f_1 is the focal
length of cylindrical lens surfaces 6. Photosensor 24
may be any type of device which produces an electrical
20 output dependent only upon the total intensity of
light striking the surface of photosensor 24, such as,
for example, a photocell having uniform light
measuring sensitivity across its light sensitive
surface. Photosensor 24 is equipped with a shutter 26
25 which may be used to block the light of beam 18 from
reaching the light sensitive surface of photocell 24
during the write operation.

In another embodiment of the invention laser
16 and photosensor 24 may both be located on the same
30 side of recording plate 2 or recording disk 8. This
may be accomplished by simply covering data surface 12
with a mirror coating of highly reflective material,
thus forming a mirror surface which reflects beam 18
back toward laser 16, and by also employing a beam
35 splitter mirror (such as a dichroic beam splitting
mirror) located above recording plate 2 or recording
disk 8, inclined at an angle (typically about 45°) to
beam 18, to divert a portion of the reflected beam to

1 photosensor 24, which is located above and to one side
of recording plate 2, in the optical path of light
rays reflected both from the mirror surface and the
beam splitter mirror.

5 Laser 16, cylindrical lens 20 and
photosensor 24 are fixed in position with respect to
one another, each being connected to an optical
housing 28, either directly or by means of connecting
rods or similar structures. Recording plate 2 is not
10 attached directly to optical housing 28, so that
relative translational and rotational motion is
allowed, as further discussed below. All of these
components are connected directly or indirectly to a
base 30. Optical housing 28 and recording plate 2 may
15 be connected to base 30 through support posts attached
to base 30 in a manner well known in the art. In the
embodiment of the invention using recording disk 8,
said disk is supported by a spindle connected to drive
motor 10, which is connected to base 30, as indicated
20 in Figure 4. As further discussed below, relative
translational motion of optical housing 28 and
recording plate 2 may be accomplished by use of linear
electric drive motors (not shown) interposed between
recording plate 2 and its support post, or between
25 optical housing 28 and its support post. In the
recording disk embodiment such relative translational
motion may be accomplished by a linear electric drive
motor interposed between base 30 and drive 10.

30 When it is desired to record binary data,
shutter 26 is closed and recording plate 2 is moved
longitudinally - i.e. in the direction of the axes of
cylindrical lens surfaces 6. Laser 16 is pulsed at
high power for each 1 bit to be recorded, forming a
point image 22 on data surface 12, at the
35 corresponding position on data line 14, thereby
changing the light transmitting characteristics of
data surface 12 at the location of image 22. The 0

1 bits are represented by the absence of such images at
other positions on data line 14, at which positions
the light transmitting characteristics of data surface
12 are unchanged.

5 Applicant's apparatus is not limited in its
application, to the recording and readout of binary
data. Analog recording may also be accomplished: the
focused beam from laser 16 may be applied with
continuously varying intensity, so as to produce
10 continuous variations (along each of the data lines
14) of the light transmitting characteristics of data
surface 12.

To read data previously recorded, laser 16
is switched to low power continuous operation, shutter
15 26 is opened, and recording plate 2 is again moved
longitudinally. Beam 18 and photosensor 24 in this
mode together read the data previously recorded on
data line 14, which data is reflected by time
variations in the electrical output of photosensor 24.

20 As illustrated in Figs. 2 and 3, the light
rays of beam 18 in each cross sectional plane
(perpendicular to the axis of cylindrical lens surface
6) are parallel when striking the upper surface of
recording plate 2. Moreover, photosensor 24 gathers
25 all of the light diverging from image 22. Thus, the
performance of the apparatus is quite insensitive to
any vertical wobbling motion of recording plate 2.

Fig. 2 illustrates the effect of eccentric
(horizontal) motion of recording plate 2, with respect
30 to beam 18. As recording plate 2 moves to the shifted
position indicated by dashed lines, image 22 formed by
a particular cylindrical lens surface 32, moves with
cylindrical lens surface 32, so that image 22
remains at the same point on shifted data
35 surface 12. Thus applicant's apparatus does not
require the use of a tracking servomechanism which
monitors the eccentric motion of recording plate 2 so
as to maintain the focus of image 22 on a given data

1 line. Such a mechanism could of course be employed,
however, in particular applications, to achieve even
greater reliability, data density and data rate.

5 Beam 18 has a width slightly greater than
the width of each cylindrical lens surface 32, and
beam 18 is of sufficient width that the entire width
of lens surface 32 is covered by beam 18 in both the
original and shifted positions, for the eccentric
motions to be encountered. Thus, there is no
10 appreciable diminution of the total light flux
reaching image 22 and therefore no appreciable effect
on the output of photosensor 24 as a result of the
eccentric motion, during the data reading operation.
However, since beam 18 covers slightly more than the
15 entire width of a cylindrical lens surface 32, a
portion of beam 18 will always fall upon the adjacent
cylindrical lens surface 34. A portion of beam 18
will thus be diverted to form a secondary image 36 on
the focal line of adjacent cylindrical lens surface
20 34, with no corresponding diminution of the total
light flux reaching image 22, provided the width of
beam 18 is sufficient to cover the entire width of
lens surface 32 in both the original and shifted
positions. The diverted light will however miss the
25 photosensor and be of no consequence during the data
reading operation. During the data writing operation
the diverted light will not produce an erroneous data
record at the position of secondary image 36. Only a
very small portion of the light will be diverted,
30 since the width of beam 18 only slightly exceeds the
width of lens surface 32, and since the distribution
of the light intensity drops off rapidly near the
edges of beam 18.

35 As already noted, the precise position of the
date line 14 formed by a given cylindrical lens
surface 6 will depend upon the angle of incidence of
the beam 18 at the upper surface of recording plate 2.
By rotation of optical housing 28 with respect to

1 recording plate 2, about the axis of one of the
cylindrical lens surfaces 32, as illustrated in Fig.
3, numerous data lines may be formed beneath one of
the cylindrical lens surfaces 6. In this manner, and
5 because each of the images 22 is approximately a point
image, a very high area density of binary data storage
may be achieved. In the case of the recording disk
embodiment of the invention, the relative rotation
will be about the axis of the particular cylindrical
10 lens surface 32 at the point of contact of beam 18--
that is, about a line tangent to cylindrical lens
surface 32 at said point of contact.

Of course only relative rotation of optical
housing 28 and recording plate 2 (or recording disk 8)
15 is required. Such relative rotation may be achieved
by holding either of these components fixed and
rotating the other. Although the specific means
disclosed below is one for rotating optical housing
28, those familiar with the art will appreciate that
20 the same means could instead be used to rotate
recording plate 2 (or to rotate the plane of recording
disk 8), by being attached to recording plate 2 (or
recording disk 8) and base 30, without departing from
the spirit or substance of the invention. Of course
25 the same type of rotation means described below could
instead be attached to recording plate 2 (or recording
disk 8) and optical housing 28, in order to achieve
the desired relative rotation. Since optical housing
28 and recording plate 2 (or recording disk 8) are
30 each connected directly or indirectly to base 30, the
rotation means is in either of these cases connected
(directly or indirectly) to optical housing 28, to
recording plate 2 (or recording disk 8), and to base
30.

35 Fig. 3 shows a cross section of five of the
cylindrical lens surfaces 6 of the recording plate 2.
The optical write-read system is shown centered over
the middle cylindrical lens surface. Laser 16,

1 cylindrical lens 20 and photosensor 24 are together
rotated with respect to recording plate 2, by rotation
of optical housing 28, over an angle A in order to
scan over the recorded data lines 14 from data line 38
5 to data line 40. The axis of rotation is the axis of
curvature of the particular cylindrical lens surface 6
being used. Intermediate angles will of course select
intermediate data lines 14. In this manner any data
line 14 may be selected by simply rotating the optical
10 system by an appropriate angle. Once this angle is
set and locked, there is no further need to track the
data lines.

The angular accuracy required to scan among
the data lines 14 is determined from the geometry of
15 Fig. 3. The total angle scanned to cover, for
example, 200 lines recorded between data line 38 and
data line 40 is determined by distance from the axis
of rotation to data surface 12. This total angle is
indicated by the angle A in the figure.

20 The value of the angle A is dependent on the
value of many design parameters. In the preferred
embodiment the width of the cylindrical lens surfaces
6 was chosen to be 0.1016 centimeters (cm). The
thickness f_1 of the recording disk 8 is 0.3175 cm.
25 The material of the disk is methyl methacrylate.
These choices result in the proportions shown in Fig.
3 and the angle A is about 27 degrees. The angle
between data lines 14 is then $27/200$ degrees or 0.135
degrees. This is a very reasonable angle that can be
30 accurately set by ordinary mechanical means.

Fig. 4 shows a specific means for rotating
optical housing 28, which is shown as applied to the
recording disk embodiment of the invention. A sector
gear 42 is securely attached to optical housing 28.
35 The radius of sector gear 42 is 7.4371 cm. A worm
gear 44 is meshed with sector gear 42, and has a pitch
of 0.0706 cm or 14.173 turns per cm. With this
combination a $1/4$ turn of worm gear 44 will move the

1 optical system through exactly 0.135 degrees which
corresponds to one data line spacing. Worm gear 44 is
turned by means of a stepping motor 46 and a second
worm gear 48. The gear system of second worm gear 48
5 has a reduction ratio of 20. The stepping motor 46
rotates 1/4 turn for each pulse received from a
stepping motor control unit 50. Therefore each pulse
scans the optical system over 1/20 of a data line
separation. Other combinations of turns per pulse and
10 gear ratios can be used with equal results.

When a new recording disk 8 is inserted into
the system, alignment must be achieved on at least one
data line 14. The adjacent data lines 14 may be
accessed by sending 20 pulses of the proper polarity
15 to stepping motor 46. Initial alignment is achieved
by means of a photosensor 24 in the form of a
photocell 52 which is split into two closely spaced
sections (hereinafter "bi-cell"). When the system is
aligned so that a given data line 14 is perceived by
20 both halves of the bi-cell equally, then the optical
system is centered on that data line. Small mis-
alignments of greater than 5% of the track spacing
will cause a single correction pulse to be sent to
stepping motor 46, by means of a bi-cell comparator
25 54, which instructs the stepping motor control unit 50
to send a pulse to the stepping motor 46. The single
pulse process is repeated until the optical system is
aligned to the center of the data lines 14.

Bi-cell comparator 54 is a two input
30 amplifier having high output when the first input is
higher than the second; the output is low if the
reverse is true. Stepping motor control unit 50 is a
microprocessor and pulse generator which sends phased
pulses to stepping motor 46, with such phase as to
35 rotate stepping motor 46 clockwise if the input to
stepping motor control unit 50 is high, and
counterclockwise if said input is low.

The track to track selection may be made by.

1 a computer logic unit which sends 20 pulses to the
stepping motor 46 to move from data line to data line.
The signal from both halves of the bi-cell is summed
and sent to the computer as the data signal from the
5 recording disk 8.

Those familiar with the art will appreciate
that the above-described means for rotation of optical
housing 28 simply constitutes one particular means for
rotating optical housing 28, and for reliably
10 selecting specific angular orientations of optical
housing 28. Other equivalent means may, of course, be
used without departing from the substance of the
invention.

Of course it will be necessary not only to
15 record or read the data lines 14 beneath a given one
of the cylindrical lens surfaces 6, but also to switch
to the separate sets of data lines corresponding to
other cylindrical lens surfaces. This may readily be
accomplished by simple relative translational motion
20 of optical housing 28 and recording disk 8 (or
recording plate 2 in the other embodiment) in a
direction perpendicular to the axis of the particular
cylindrical lens surface currently receiving the beam
18 (i.e. in the direction of the radius of recording
25 disk 8 through image 22, in the embodiment of Fig. 4).
Such relative translation may be accomplished by means
of a linear electric drive motor (not shown) connected
to base 30 (or to optical housing 28) and to recording
disk 8 (or recording plate 2), or by such a motor
30 connected to optical housing 28 and base 30.

In the recording disk embodiment of Fig. 4
the drive motor 10, a turntable-type electric motor,
provides the means for moving recording disk 8 in the
axial direction of the cylindrical lens surface 6 at
the position of image 22, by rotating recording disk
35 8, so as to allow recording or reading along a given
data line 14, for a fixed orientation of optical
housing 28. In the other embodiment of the invention,

1 in which recording plate 2 has a rectilinear lens
array 4 of cylindrical lens surfaces 6 having parallel
straight line axes, the corresponding motion is simple
relative translational motion of optical housing 28
5 and recording plate 2, in a direction parallel to the
axes of cylindrical lens surfaces 6, which may be
accomplished by means of a linear electric drive motor
(not shown) connected to base 30 (or to optical
housing 28) and to recording plate 2, or by such a
10 motor connected to optical housing 28 and base 30.

Since optical housing 28 and recording plate
2 (or recording disk 8) are each connected directly or
indirectly to base 30, the above-described means for
achieving relative translational motion of optical
15 housing 28 and recording plate 2 (or recording disk 8)
are, in each of the above-described configurations,
connected (directly or indirectly) to optical housing
28, to recording plate 2 (or recording disk 8) and to
base 30.

20 In the preferred embodiment the means which
rotate and translate the optical housing 28 are
attached not only to the optical housing 28 but also
to a base 30 of the entire apparatus, to which base
are also attached the above-described means for
25 rotating the recording disk 8, or for translating the
recording plate 2. Base 30 is a plate secured to the
floor, and simply constitutes one possible support
means for providing a fixed support. Any other
suitable fixed frame or other suitable fixed structure
30 could of course be used instead.

Those familiar with the art will appreciate
that the invention may be employed in specific
configurations and embodiments other than those
specifically disclosed herein, without departing from
35 the spirit and substance thereof. The essential
characteristics of the invention are defined by the
following claims.

1 I claim:

1. - Optical data storage and readout apparatus.
comprising:

5 (a) a support means, for providing a fixed
support;

(b) an optical housing connected to said
support means;

10 (c) a recording plate connected to said
support means, which recording plate is a flat
transparent plate having on one surface thereof a
cylindrical lens array comprising a plurality of
convex cylindrical lens surfaces with parallel axes,
each having a focal length equal to the thickness of
said plate; and having on the other surface thereof a
15 data surface comprising a coating of a material which
will change its light transmitting characteristics
upon exposure to high intensity light;

20 (d) a means, connected to said recording
plate, to said optical housing, and to said support
means, for producing relative translational motion of
said recording plate with respect to said optical
housing, said motion being parallel to said axes of
said cylindrical lens surfaces;

25 (e) a rotation means, connected to said
recording plate, to said optical housing, and to said
support means, for producing relative rotational
motion of said optical housing with respect to said
recording plate, said rotational motion being about an
axis of one of said cylindrical lens surfaces, and for
30 selecting and reproducing specific angular
orientations of said relative rotational motion;

(f) a means, connected to said recording
plate, to said optical housing and to said support
means, for producing relative translational motion of
35 said optical housing with respect to said recording
plate, said motion being in a direction perpendicular
to said axes of said cylindrical lens surfaces, and
parallel to the surface of said recording plate;

1 (g) a light means, connected to said optical
housing, located on the side of said recording plate
bearing said cylindrical lens array, for generating a
beam of initially parallel light rays directed onto
5 said cylindrical lens array in a direction
perpendicular to said axes of said cylindrical lens
surfaces;

(h) a convex cylindrical lens, having a
focal length greater than the thickness of said
10 recording plate, connected to said optical housing,
located between said light means and said recording
plate, at a distance from said data surface of said
recording plate such that the focal point of said
cylindrical lens lies on said data surface, so
15 positioned as to intercept said beam of parallel light
rays, and aligned essentially perpendicular to said
axes of said cylindrical lens surfaces;

(i) a photosensor means for producing an
electrical signal of amplitude dependent upon the
20 intensity of light incident upon the surface of said
means, without regard for the distribution of such
light upon such surface, said means being connected to
said optical housing, said means being located in the
optical path of said light rays after said light rays
25 have passed through said data surface, said
photosensor means having a shutter and having an
aperture not less than (DW/f_1) , where D is the
distance along the optical path of said light rays
from said data surface to said photosensor means, W is
30 the maximum width of said beam at the point of
incidence of said beam with said recording plate, and
 f_1 is the focal length of said cylindrical lens
surfaces; said photosensor means being positioned
essentially on the axis of said beam.

35 2. Optical data storage and readout apparatus,
comprising:

(a) a support means, for providing a fixed
support;

1 (b) an optical housing connected to said support means;

 (c) a recording disk rotatably connected to said support means, said recording disk being a flat
5 transparent disk having on one surface thereof a cylindrical lens array comprising a plurality of cylindrical lens surfaces with axes forming circles concentric with said disk, each of said cylindrical lens surfaces having a focal length equal to the
10 thickness of said disk; and having on the other side thereof a data surface comprising a coating of a material which will change its light transmitting characteristics upon exposure to high intensity light;

 (d) a first rotation means, connected to said recording disk and to said support means, for
15 rotating said recording disk about the axis of said recording disk;

 (e) a light means connected to said optical housing, located on the side of said recording disk bearing said cylindrical lens array, for generating a
20 beam of initially parallel light rays directed onto said cylindrical lens array in a direction perpendicular to said axes of said cylindrical lens surfaces at the point of contact of said beam with said recording disk;

25 (f) a second rotation means, connected to said recording disk, to said optical housing, and to said support means, for producing relative rotational motion of said optical housing with respect to said recording disk, said rotational motion being about a
30 line tangent to the cylindrical lens surface of said recording disk intersected by said beam at the point of intersection of said cylindrical lens surface and said beam, and for selecting and reproducing specific angular orientations of said relative rotational
35 motion;

 (g) a means, connected to said recording disk, to said optical housing, and to said support

1 means, for producing relative translational motion of
said optical housing with respect to said recording
disk, said motion being in the direction of the
radius of said recording disk intersecting said beam;

5 (h) a convex cylindrical lens, having a
focal length greater than the thickness of said
recording disk, connected to said optical housing,
located between said light means and said recording
disk, at a distance from said data surface of said
10 recording disk such that the focal point of said
cylindrical lens lies on said data surface, so
positioned as to intercept said beam of parallel light
rays, and aligned essentially parallel to the radius
of said recording disk intersecting said beam;

15 (i) a photosensor means for producing an
electrical signal of amplitude dependent upon the
intensity of light incident upon the surface of said
means, without regard for the distribution of such
light upon such surface, said means being connected to
20 said optical housing, said means being located in the
portion of the optical path of said light rays after
said light rays have passed through said data surface,
said photosensor means having a shutter and having an
aperture not less than (DW/f_1) , where D is the
25 distance from said data surface to said photosensor
means, W is the maximum width of said beam at the
point of incidence of said beam with said recording
disk, and f_1 is the focal length of said cylindrical
lens surfaces; said photosensor means being positioned
30 essentially on the axis of said beam.

3. The apparatus of claim 1 wherein said
photosensor means is located on the side of said
recording plate opposite the side on which said light
means is located.

35 4. The apparatus of claim 2 wherein said
photosensor means is located on the side of said
recording disk opposite the side on which said light
means is located.

1 5. The apparatus of claim 1, further
comprising a mirror coating of reflective material
covering said data surface, and a beam splitter mirror
located above said recording plate in the portion of
5 the optical path of said light rays after said light
rays have passed through said data surface and have
been reflected from said mirror coating, wherein said
photosensor means is located above said recording
plate in the portion of said optical path after said
10 light rays have been reflected from both said mirror
coating and said beam splitter mirror.

 6. The apparatus of claim 2, further
comprising a mirror coating of reflective material
covering said data surface, and a beam splitter mirror
15 located above said recording disk in the portion of
the optical path of said light rays after said light
rays have passed through said data surface and have
been reflected from said mirror coating, wherein said
photosensor means is located above said recording disk
20 in the portion of said optical path after said light
rays have been reflected from both said mirror coating
and said beam splitter mirror.

 7. The apparatus of any of the preceding
claims, wherein said light means is a laser.

25 8. The apparatus of any of claims 1 through
6, wherein said photosensor means is a photo cell
having uniform light gathering sensitivity across the
photosensitive surface of said photo cell.

 9. The apparatus of claims 2, 4 or 6,
30 wherein the thickness of said recording disk is
approximately 0.3175 cm and the width of said
cylindrical lens surfaces is approximately 0.1016 cm.

 10. The apparatus of claims 1, 3 or 5,
35 wherein the thickness of said recording plate is
approximately 0.3175 cm and the width of said
cylindrical lens surfaces is approximately 0.1016 cm.

1 11. The apparatus of claims 1, 3, or 5
wherein said recording plate is composed of methyl
methacrylate.

5 12. The apparatus of claims 2, 4, or 6,
wherein said recording disk is composed of methyl
methacrylate.

10 13. The apparatus of any of claims 1
through 6, wherein said beam of parallel light
generated by said light means has a diameter slightly
greater than the width of each of said cylindrical
lens surfaces of said cylindrical lens array.

15 14. The apparatus of any of claims 1
through 6, wherein said data surface comprises a
coating of tellurium approximately 5 microns thick.

20 15. The apparatus of any of claims 1
through 6, wherein said data surface comprises a
coating of photosensitive material which is capable of
forming a photographic image upon exposure to focused
laser light.

25 16. The apparatus of any of claims 1
through 6, wherein said data surface comprises a
coating of a ferromagnetic material.

30

35

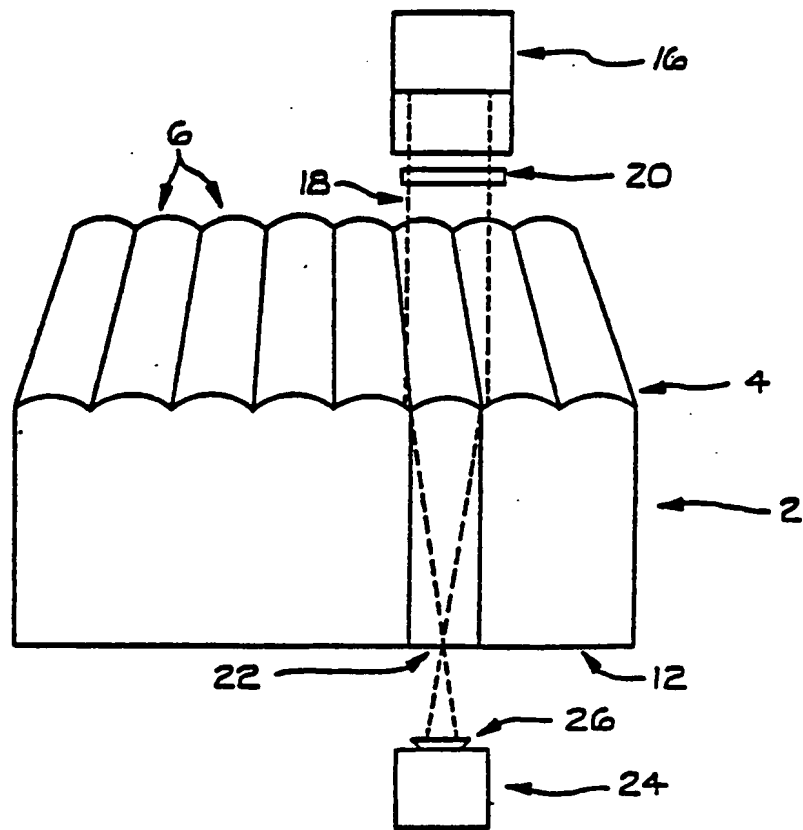


FIG 1

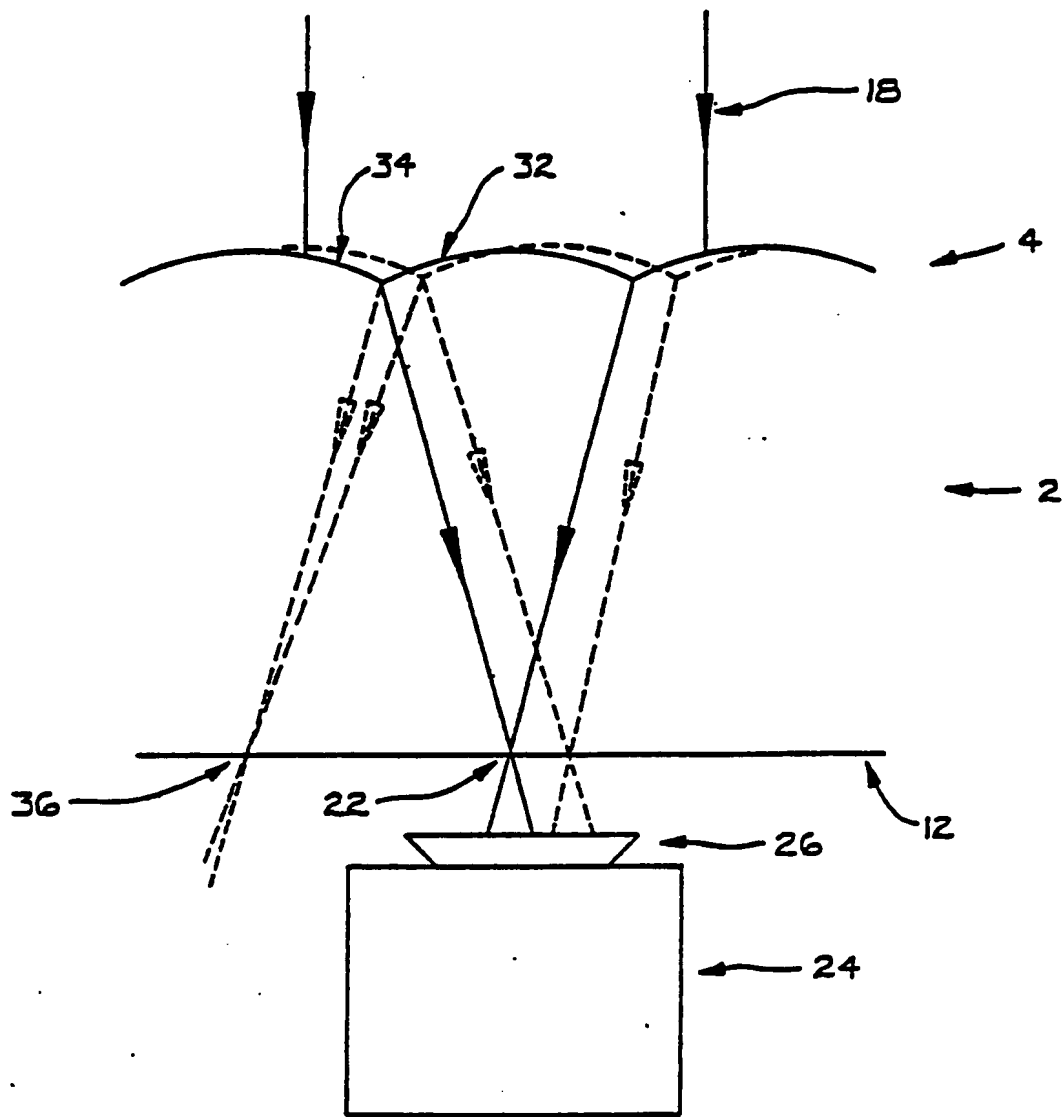


FIG 2

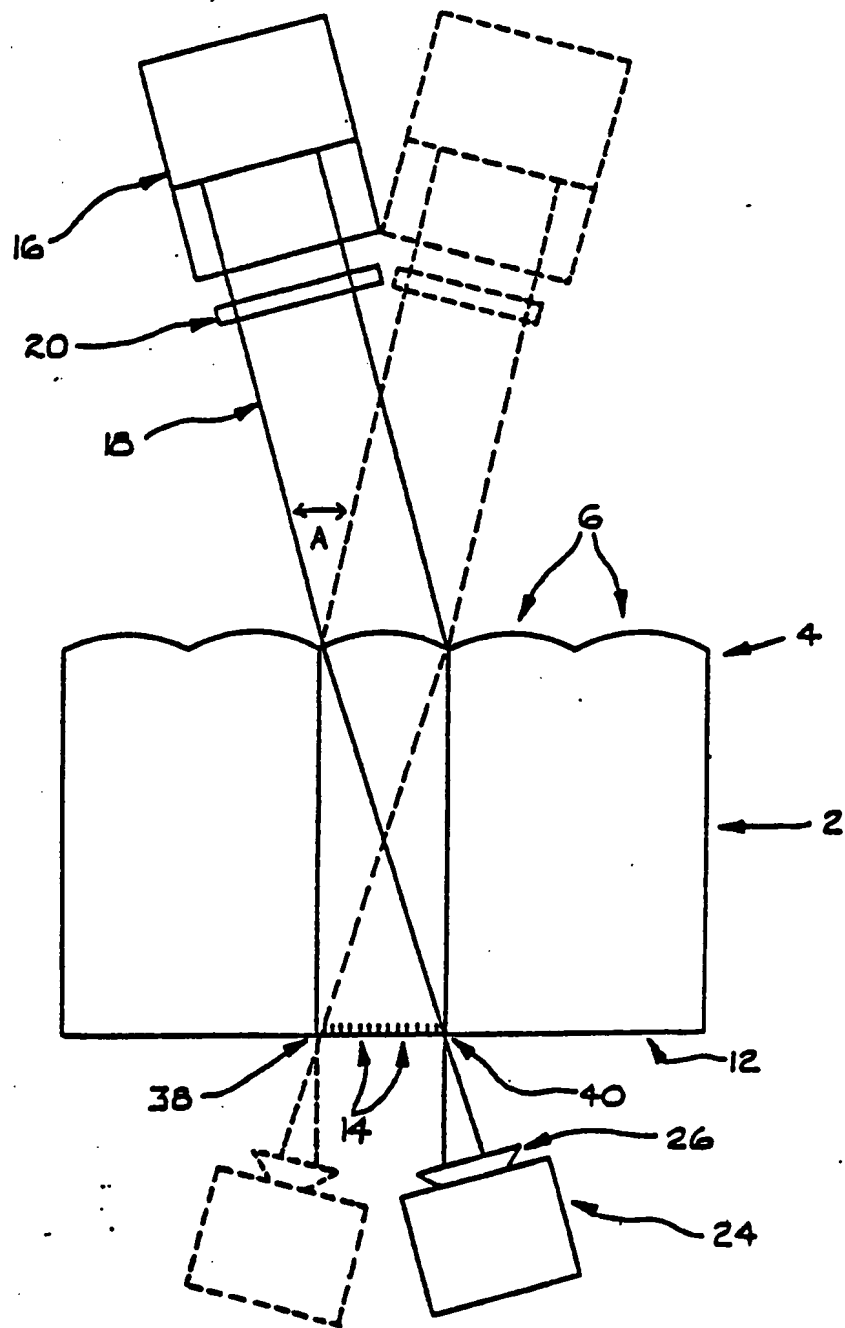


FIG 3

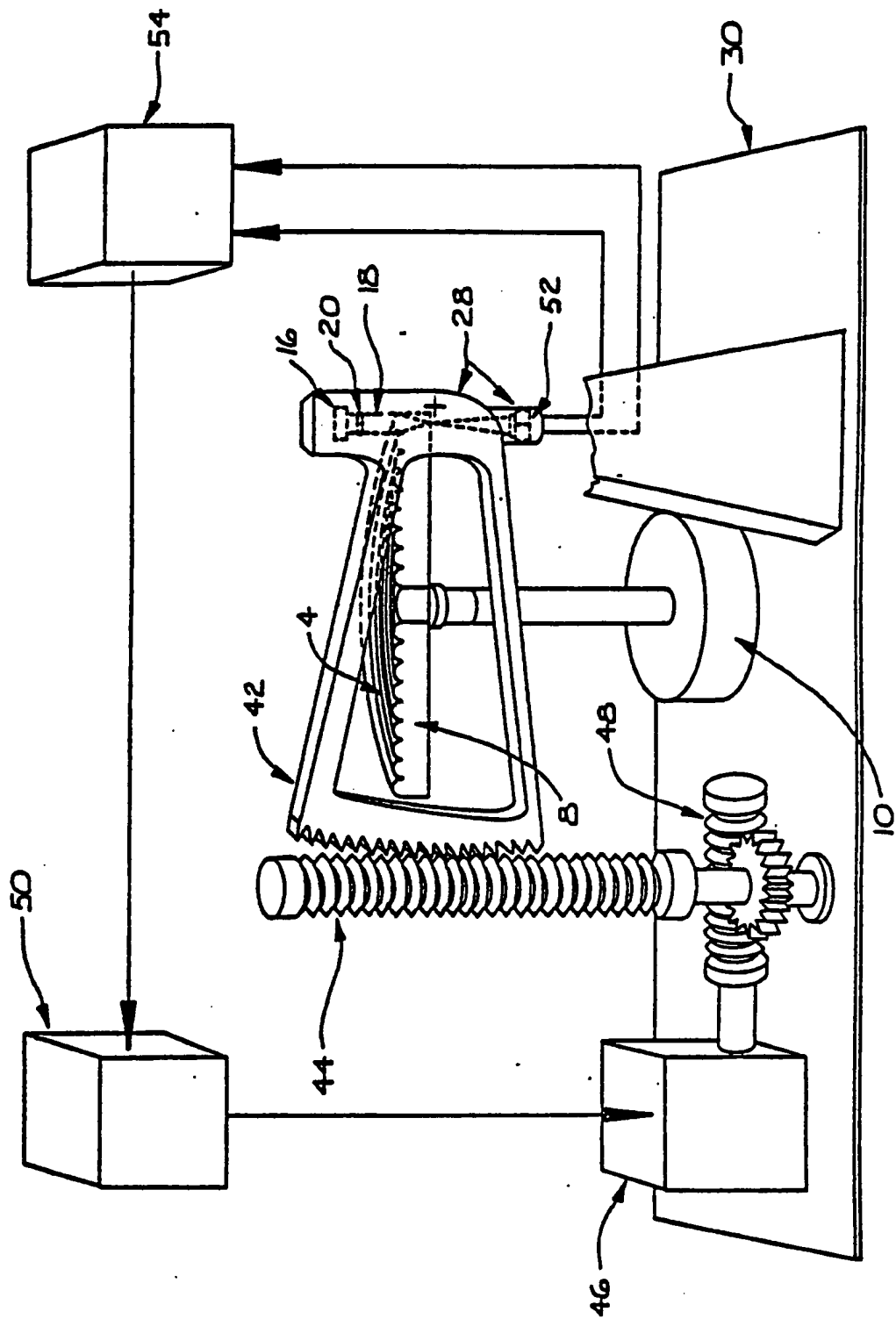


FIG 4

INTERNATIONAL SEARCH REPORT

International Application No PCT/US85/00006

I. CLASSIFICATION OF SUBJECT MATTER (If several classification symbols apply, indicate all) ³		
According to International Patent Classification (IPC) or to both National Classification and IPC		
INT. CL. ³	G 11B 7/12	
U.S. CL.	369/112	
II. FIELDS SEARCHED		
Minimum Documentation Searched ⁴		
Classification System	Classification Symbols	
U.S.	369/111, 112, 117, 118, 283, 284, 286, 275; 365/120, 127; 346/76L, 135.1, 137	
Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched ⁵		
III. DOCUMENTS CONSIDERED TO BE RELEVANT ¹⁴		
Category ¹⁵	Citation of Document, ¹⁶ with indication, where appropriate, of the relevant passages ¹⁷	Relevant to Claim No. ¹⁸
Y	US, A, 2,092,892, (Runge), 14 September 1937	1-13
Y	US, A, 1,956,626, (Robbins), 01 May 1934	1-13
Y	US, A, 2,077,518, (Eggert), 20 April 1937	1-13
Y	US, A, 3,944,727, (Elliott), 16 March 1976	1-13
Y	US, A, 3,818,148, (Dickopp), 18 June 1974	1-13
A	US, A, 4,020,278, (Carre), 26 April 1977	1-13
A	US, A, 2,923,781, (Gordon), 02 February 1960	1-13
A	US, A, 3,427,942, (Browning), 18 February 1969	1-13
A	US, A, 3,999,008, (Bouwhuis), 21 December 1976	1-13
<div style="display: flex; justify-content: space-between;"> <div style="width: 48%;"> <p>¹⁵ Special categories of cited documents:</p> <p>"A" document defining the general state of the art which is not considered to be of particular relevance</p> <p>"E" earlier document but published on or after the international filing date</p> <p>"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)</p> <p>"O" document referring to an oral disclosure, use, exhibition or other means</p> <p>"P" document published prior to the international filing date but later than the priority date claimed</p> </div> <div style="width: 48%;"> <p>"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention</p> <p>"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step</p> <p>"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.</p> <p>"&" document member of the same patent family</p> </div> </div>		
IV. CERTIFICATION		
Date of the Actual Completion of the International Search ¹	Date of Mailing of this International Search Report ²	
27 February 1995	15 MAR 1985	
International Searching Authority ¹	Signature of Authorized Officer ²⁰	
ISA/US	Alan Faber	

FURTHER INFORMATION CONTINUED FROM THE SECOND SHEET

V. ☐ OBSERVATIONS WHERE CERTAIN CLAIMS WERE FOUND UNSEARCHABLE ¹⁰

This international search report has not been established in respect of certain claims under Article 17(2) (a) for the following reasons:

1. ☐ Claim numbers _____, because they relate to subject matter ¹² not required to be searched by this Authority, namely:

2. ☐ Claim numbers _____, because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out ¹³, specifically:

VI. ☒ OBSERVATIONS WHERE UNITY OF INVENTION IS LACKING ¹¹

This international Searching Authority found multiple inventions in this international application as follows:

Invention I : Claims 1-13

Invention II : Claim 14

Invention III: Claim 15

Invention IV : Claim 16

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims of the international application.

2. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims of the international application for which fees were paid, specifically claims:

3. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claim numbers:

4. ☐ As all searchable claims could be searched without effort justifying an additional fee, the International Searching Authority did not invite payment of any additional fee.

Remark on Protest

☐ The additional search fees were accompanied by applicant's protest.

☐ No protest accompanied the payment of additional search fees.